Mammoth Hot Springs Geological Background

The spring water at Mammoth comes from rain water and snow melt that enters the groundwater at the southern edges of the Gallatin Mountain Range. It percolates into the deep subsurface along these fault systems and may spend as little as 2000 to more than 11,000 years during this hydrologic transit (Rye and Truesdell, 2007). As it travels, the water flows through and dissolves limestone and evaporite rocks (sedimentary deposits resulting from evaporation of seawater) that were deposited approximately 350 million years ago during the Mississippian Period (Sorey, 1991). The water becomes super-saturated with dissolved carbonate minerals and CO_2 gas. It is also heated to more than 100°C (212°F) by volcanic rock that has been heated by the underlying Yellowstone hotspot. This forces the groundwater to rise to the surface through large subsurface fracture systems at Mammoth.

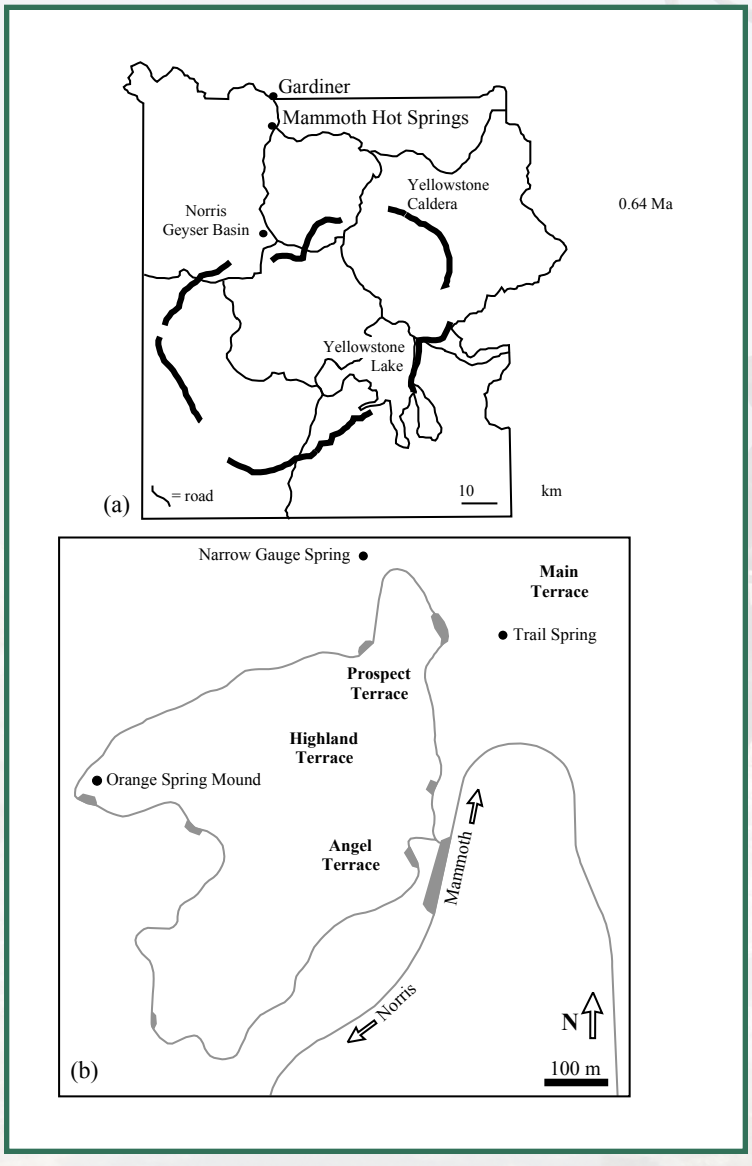

Figure 1 (courtesy of B.W. Fouke)

The spring water emerges from the vents at Mammoth at a temperature of around 73°C (163°F) and with a neutral pH of 6. As it hits the air, the water goes through a chemical process in which some of the carbon dioxide (CO_2) leaves, or degasses, from the water making it less acidic (noted by a rapid increase in the water's pH) and creating favorable conditions for rapid calcium carbonate ($CaCO_3$) mineral accumulation, called precipitation (Friedman, 1970), forming the characteristic terraces at Mammoth Hot Springs. The precipitation of the calcium carbonate ($CaCO_3$) minerals aragonite and calcite forms a rock, which as a whole is referred to as travertine. Travertine precipitation in locations where the water continually flows at Mammoth Hot Springs has been recorded at rates upwards of 5mm or ¼ in/day and as much as 1m in a single year (Fouke et al., 2000; Kandianis et al., 2008; Veysey & Goldenfeld, 2008). Figures 2a and 2b demonstrate this type of accumulation recorded by STaRRS teachers and students at Narrow Gauge during the 2008-2009 school year. In geologic terms, this rock growth rate occurs at light speed – millions to billions times faster than caves and deep sea floor.

Figure 2 - Photopoint Photos taken at Narrow Gauge Hot Spring. Figure by A. Houseal

Travertine precipitates in a variety of distinct crystalline shapes and forms that systematically change from upstream to downstream within each drainage pattern (Fouke et al. 2000). More information on these systematic changes can be found in the Background information on the Hot Springs Facies Model section of the curriculum.

The distinct shapes and forms also produce an environment conducive to communities of often colorful, heat-loving (thermophilic) microorganisms (microbes). They exhibit a wide range of colors and shapes, growing in large communities called microbial mats. The microbial mats, composed of bacteria and archaea populations, are an important part of this $CaCO_3$ precipitation process. They have been found to grow even more quickly than the travertine precipitation (Fouke, 2011), and they help form the long-term accumulation of thick travertine deposits (Kandianis et al., 2008).

Over time travertine deposits formed, first in Gardiner and more recently at Mammoth Hot Springs. The deposits in Gardiner are now privately owned quarries where travertine is mined for uses such as countertops and floors. Although the initial deposits of travertine are quite fragile, over time, atmospheric water percolates through the travertine, causing chemical changes in the rock, which strengthens it. Even though there are many travertine-depositing hot springs throughout the world, Mammoth Hot Springs is unique due to the long-term protection of the National Park Service.

Common questions associated with MHS

How old, thick, and large are the travertine deposits?

The Gardiner travertine is 31,000 years old, while the travertine at Mammoth Hot Springs ranges in age from 0 to nearly 8000 years before present (Sturchio et. al, 1994; Butler, 2008; Vescogni, 2009). The travertine terrace deposits at Mammoth are 73m thick and cover an area more than 4km2 (Allen & Day, 1935; White et al., 1975). The terraced travertine deposits at Gardiner, which are now a part of a privately owned quarry, are basically the same size (Sorey, 1991).

Why do the springs "shut down"? & Do the vents get clogged by the travertine?

There are two current hypothetical explanations for why the springs "shut down" or undergo plumbing changes. One is that some type of ground movement, such as the thousands of earthquakes that occur in YNP each year, may cause underground plumbing to clog and/or reopen in other locations. Another hypothesis is that the weight of the travertine in any given spring succumbs to gravity, causing other shifts in the plumbing. A third, older hypothesis regarding the "clogging" of the vent (the opening where the water emerges) by the depositing travertine has recently been called into question by comparing the pH levels needed for travertine precipitation (>6.1) and the pH levels of spring water emerging from the vent (6.0). The water is just slightly too acidic for deposition to occur, thus it cannot clog the vent (Fouke, 2011).

Is the flow of water in MHS decreasing/increasing?

The flow of water in MHS is thought to be constant throughout the entire spring system though in any given spring, it can fluctuate wildly in hours, days, weeks, and months (Friedman, 1970). It can appear to be decreasing or increasing dramatically in one location. There are many places on the Upper and Lower Terraces that are unsafe for visitors to view, and sometimes, the flow in these locations increases when the flow in other, more visible spots decreases.

MHS Geological Background

Why doesn't the travertine completely fill in all of MHS?

First of all, most of the main flow paths are relatively small in size and run for a relatively short duration. Some may flow for hours, others for years, but even those that flow for years experience extreme differences in the rate of spring water flow. The accumulation of travertine can also alter the flow path, causing it to shift and build up in another location

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